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6. AUTHOR(S)
Frank S. Henyey

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Applied Physics Laboratory
University of Washington
1013 NE 40th Street
Seattle, WA 98105-6698

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13. ABSTRACT *(Maximum 200 words)*

The goal of this research is to understand internal waves in the ocean, and their relationship to other oceanographic phenomena, especially the dissipation of energy. Work carried out included a study of the energetics of the coastal-region tidally-generated internal waves we call "solibores," and two topics in the formal theory of the Hamiltonian description of ocean dynamics.

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Frank S. Henyey

Modeling and Theory of the Internal Wave Field

Applied Physics Laboratory, University of Washington
1013 NE 40th St., Seattle WA 98105
e-mail: frank@apl.washington.edu
ph. (206)543-4856; fax (206)543-6785

The goal of this research is to understand internal waves in the ocean, and their relationship to other oceanographic phenomena, especially the dissipation of energy. Theoretical and numerical modeling studies of various internal wave situations are carried out, often using techniques that have been developed in theoretical physics. Work carried out this year include a study of the energetics of the coastal-region tidally-generated internal waves we call "solibores", and two topics in the formal theory of the Hamiltonian description of ocean dynamics. In addition, two graduate students have started to use versions of the ray-trace small-scale internal wave code Henyey and collaborators developed ten years ago.

The "solibore" study was designed to test whether the energetics of these waves is similar to a bore. If it is, there is an approximate balance between the energy flux into the wave and the dissipation in the strong turbulence that occurs in it. If it is not, the dissipated energy causes the wave to decay. We found that, unlike surface bores, the kinetic energy flux removes energy from a solibore, while the potential energy flux and pressure work supply energy. Only if the wave travels slowly enough is there a net energy supply. We estimated energy supply and dissipation from data on two solibores, one in the Strait of Gibraltar (Wesson & Gregg) and one in Knight Inlet (Farmer & Smith). As the energy supply is rather sensitive to the solibore speed, we were careful to estimate the speed properly. The figure shows the Gibraltar solibore energy supply and several dissipation estimates as a function of speed, with our speed estimate shown. Our conclusion is that the data was not adequate to be sure of the energetic balance, because it was not designed for that purpose. Data designed for calculating the energy balance will be gathered at Knight Inlet next summer. A paper by Frank Henyey and Antje Höring has been submitted to JGR. Solibores are a very important part of coastal region ocean dynamics, and are expected play a role in many coastal studies. In particular, they are likely to be important in shallow water acoustics such as mine hunting. Both the wave aspects, which refract sound, and the turbulence, which scatters sound, are important.

Peter Muller (and Henry Abarbanel, earlier) claimed that potential vorticity local conservation was the "gauge" group of the Hamiltonian formulation of ocean dynamics, while Frank Henyey claimed it to be local density conservation. We discovered that both claims were correct, because there are two different Hamiltonian formulations, each with its own "gauge" group. They are so similar that nobody previously recognized the difference between them. We found the canonical transformation relating them. The "center" (a technical mathematics term in group theory) of the gauge group is a Casimir invariant, which means a quantity which is conserved no matter what the details of the Hamiltonian are. One center is arbitrary functions of potential vorticity, and the other is arbitrary functions of density. By combining these, we conjectured that any arbitrary functions of both is a Casimir invariant, which we then proved by explicit calculation. A paper by Henyey, Muller, and Jim Grochocinski is in preparation.

The Hamiltonian formulation of fluid dynamics was first developed by Clebsch in 1859. Clebsch's representation was found not to be globally valid by Francis Bretherton a number of years ago; this is not really a serious problem because a similar thing happens in particle physics theories that predict magnetic monopoles, where the practitioners have

learned to work with only local representations. The proof of Clebsch's representation in Lamb's *Hydrodynamics* assumes that the vorticity is nonzero. Frank Henyey asked a mathematics professor, Robin Graham, if he could complete the proof. Instead, Graham proved just the opposite: in the generic case a Clebsch representation does not exist in any neighborhood of a point with zero vorticity, no matter how small that neighborhood is. Graham is now investigating the same question (as well as Bretherton's question) in connection with Henyey's 1983 generalization of Clebsch's representation to stratified fluid; there are no results yet. A paper on Graham's proof is in preparation by Graham and Henyey.

Two students, Miguel Nathwani (Henyey's student) and Haili Sun (Eric Kunze's student) have started working on the "Eikonal" code for small-scale internal wave transport. Nathwani is interested in those cases that Mike Gregg has found the Henyey, Wright, and Flatté expression not adequate. Those cases are equatorial waves and waves near the Gulf Stream. Sun is interested in the role of vertical straining in dissipation. These students have been learning how to use the code, and modify it for their studies.

Statistical Information

Publications

F. S. Henyey and A. Höring "Energetics of borelike internal waves", submitted to JGR

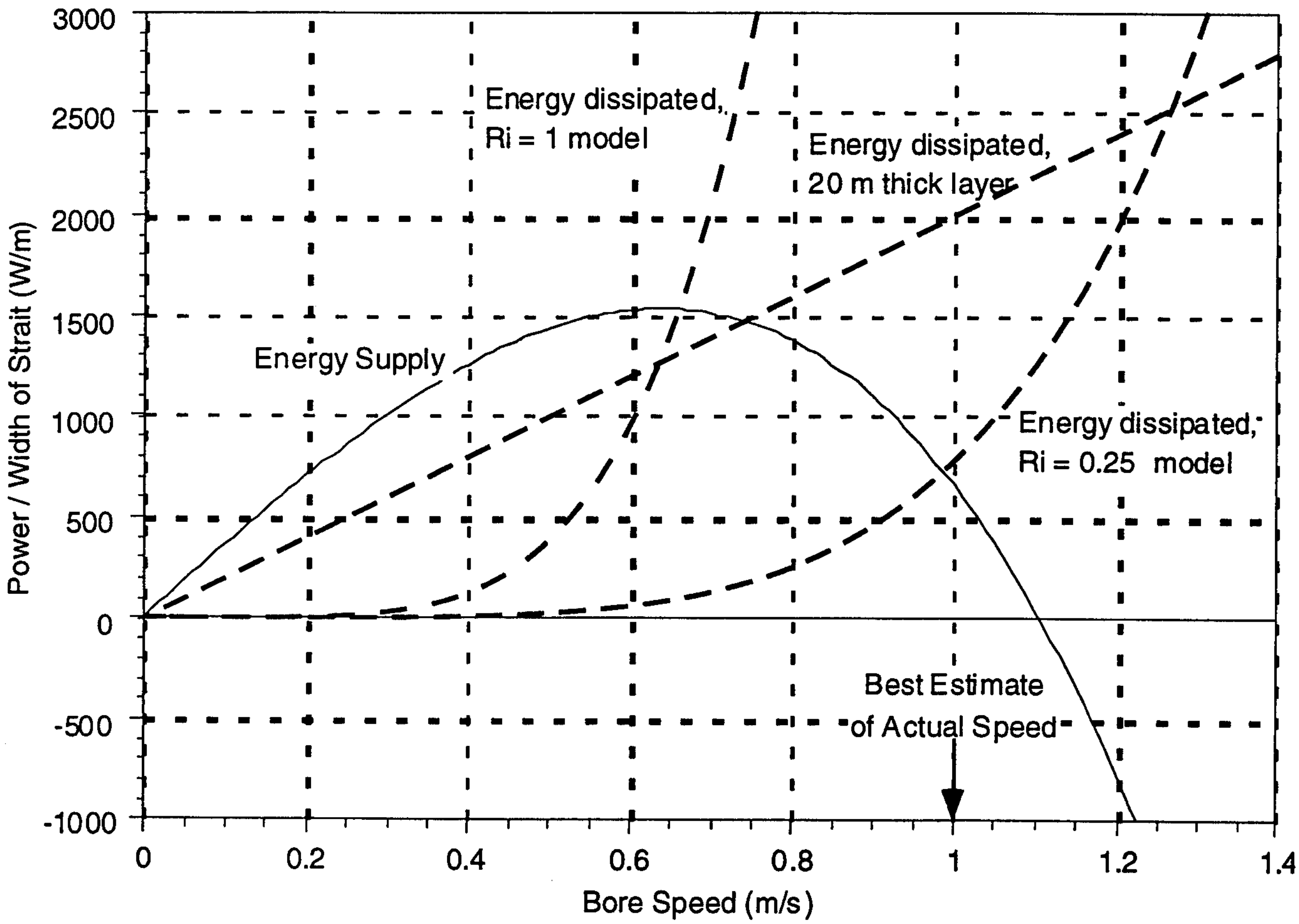
Graduate student

One physics student has been working on ocean acoustics, is starting ocean hydrodynamics.

Presentation

"Energetics of the Gibraltar Solibore" seminar at the Institute for Ocean Sciences, Sidney, British Columbia, Jun. 6, 1994

Energy Balance in a Solibore



Energy balance as a function of solibore speed: supply and dissipation for the Strait of Gibraltar. The solid curve gives our calculations for the energy supplied to the solibore. The dashed curves give the energy dissipated by the solibore based on the model of Bogucki and Garrett using both the Ri=1 criterion they advocated, a Ri=0.25 version that we prefer, and a model based on the observed final thickness of the transition region, ignoring its initial thickness. The best estimate of the solibore speed is indicated. We think it most likely that the energy supply and dissipation are within a factor of two, and possibly are closer. Based on data from Wesson & Gregg.

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